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Hydropower in Turkey: Analysis in the view of Vision 2023

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A B S T R A C T

Turkey is a recently developed country, a regional power in the Middle East and an economic powerhouse of the region. Turkey's electricity demand is continuously increasing due to fast economic growth coupled with the country's vibrant young population. It is envisaged that this demand would keep on increasing almost exponentially in the next decade according to the recently avowed Vision 2023 agenda. According to which, the Turkish government ambitiously wants to provide 30.0% of the country's electricity demand from renewable energy sources by 2023. Turkey has vast renewable energy potential including hydro, geothermal, solar and wind. However, historically there is only one playmaker that is hydropower. Thus a detailed review of the current status and future prospects of Turkish hydropower market is urgently needed to generate a roadmap for the Vision 2023 agenda. This paper was intended to provide that vital information. Currently, more than 25.0% or 57.5 TWh of the country's electricity demand is supplied from hydropower. According to official projections this would increase to approximately 116.0 TWh in 2023. In this study, hydropower's supply rate of Turkey's annual electricity demand was assessed based on the official projections and a forecast was generated. Results showed that between 22.0% and 27.0% of Turkey's annual electricity demand should be supplied from hydropower in 2023. Therefore, between 22.5 TWh and 45.0 TWh of electricity should be generated from renewable energy sources other than hydropower to provide a total of 30.0% renewable energy based electricity generation in 2023.

Contents

1. Introduction

Turkey is a member of G20 major economies, with a gross domestic product (GDP) at purchasing power parity per capita estimated at $1.075 trillion in 2011[1]. The country is an associate member of the European Union (EU), a regional power in the Middle East and an economic powerhouse of the region. Turkey's economy was one of the world's fastest growing in 2010 and 2011, with 9.2% and 8.5% annual growth, respectively [2]. It is envisaged that this economic growth will continue in the following years. Predictions about Turkey's growth rate in 2013 by International Monetary Fund (IMF), Organization for Economic Cooperation and Development (OECD), World Bank (WB), European Commission (EC), and global investment bank Goldman Sachs are 3.5%, 4.6%, 4.0%, 4.6% and 6.8%, respectively [3]. If Turkey grows only 3.5% in 2013, which is the lowest prediction so far, it still would be the fastest growing economy in the EU.

Turkey's staggering economic growth is coupled with massive electricity consumption. According to the Central Intelligence Agency (CIA), Turkey's electricity consumption in 2010 was estimated at

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201.2 billion kWh [4], which was almost double that consumed in 2000. This immense electricity demand is essentially supplied from thermal sources (fossil fuels). In 2009, approximately 61.0% of Turkey's total installed capacity for electricity generation was provided by fossil fuels; while 80.0% of the total electricity was generated from thermal power plants: for which, natural gas accounted for 49.2%, followed by coal for 40.7%, and 9.9% for liquid fuel [5]. Distribution of Turkey's installed capacity and electricity generation by power producers at the end of 2011 are reported in Table 1.

Turkey's thirst for energy is expected to increase in the foreseeable future according to the Turkish government's ambitious targets in the Vision 2023 agenda. Details of which are given in Table 2. However, Turkey does not have enough indigenous fossil fuel reserves to supply this demand. The country is a net energy importer. Mainly fossil fuels and the energy import ratio is around 65.0% [6]. Turkey imports mostly natural gas, petroleum, and hard coal, which inevitably deranges the country's macroeconomic balances [7]. According to Turkey's economy minister Mr. Zafer Caglayan, Turkey's annual trade deficit in 2011 was $100 billion [8] and more than half of this trade deficit was due to imported energy sources [9]. Fossil fuel consumption is also the dominant cause for Turkey's colossal greenhouse gas emissions. It was estimated that the energy sector contributed 285.1 million tonnes of CO_2 equivalent or 71.0% of Turkey's annual greenhouse gas emissions in 2010 [10].

Recent advances in Turkey's economy, science and technology also shaped the public perception on energy consumption and environmental protection. There is an increasing public awareness for a greener future and concern about living in a sustainable environment. Among many parameters energy is the key to sustainable development and every part of Turkey's modern society and economy depends on it. Yet it is highly questionable if Turkey can ever facilitate a truly sustainable economy. In order to tackle the country's massive dependence on fossil fuels sustainable energy sources must be utilised more and efficient means of converting and utilizing energy must be found. Without any doubt renewable energy is the solution to these challenges [11].

In Turkey, there is a huge potential for renewable energy sources [12]. Nevertheless, in 2011 only 10.0% of the total energy consumption was supplied from renewable energy sources. Therefore, the share of renewable resources in the country's energy mix must be increased without delay. In that context, Turkish government's Vision 2023 goals matches directly with this renewable energy ambition with a projected 30.0% share in the country's annual electricity generation in 2023. A general analysis of Turkey's renewable energy projection under the context of the Vision 2023 agenda is published by the author elsewhere [13]. To be specific, in this paper the author focused and analysed the current status of hydropower in Turkey and its potential role in the country's energy system between 2013 and 2023. Because, hydropower is Turkey's major renewable energy source supplying approximately 25.0% of the country's annual electricity generation and the Turkish government has a very impressive target to utilise all the technically available hydroelectric potential by 2023.

2. Hydropower in the world

Hydropower plays an essential role in many regions throughout the globe with more than 150 countries generating hydroelectric power and providing approximately 19.0% of the world's total electricity supply [14]. Hydropower also represents more than 92.0% of electricity generated from renewable resources worldwide [15]. In hydroelectric power plants (HEPPs) turbines convert water pressure into mechanical shaft power, which is then used to drive an electricity generator; the power available is proportional to the product of pressure head and water discharge [16]. Currently, it is considered as one of the most cost effective and environmentally friendly energy technologies for electricity

Table 2
Vision 2023 goals for the energy sector [54].

Area	Target
Installed power	125,000 MW
Share of renewable sources in power generation	30%
Nuclear power	eight reactors with a capacity of 10,000 MW
Nuclear power (under construction)	four reactors with a capacity of 5,000 MW
Coal power	18,500 MW
Hydropower	Full utilisation
Wind power	20,000 MW
Solar power	3000 MW
Geothermal power	600 MW

Table 1
Distribution of Turkey's installed capacity and electricity generation to the producers at the end of 2011 [44].

Producer	Type	Installed capacity, MW	Electricity generation, GWh	% of Total electricity generation
Electricity Generation Company (EUAS) Power Plants	Thermal	8690.9	73,524	32.2
	Hydropower	11,589.5		
Electricity Generation Company (EUAS) Affiliated Power Plants	Thermal	3870	18,827	8.2
Operating Rights Transferred Power Plants	Thermal	620	4552	2.0
	Hydropower	127.7		
Build-Operate Power Plants	Thermal	6101.8	44,937	19.7
Build-Operate-Transfer Power Plants	Thermal	1449.6	12,818	5.6
	Hydropower	952.8		
	Wind	17.4		
Independent Power Producers	Thermal	11,025.5	62,033	27.2
	Hydropower	3922.9		
	Geothermal	114.2		
	Wind	1710.1		
Auto-production Power Plants	Thermal	2473.3	11,716	5.1
	Hydropower	544.2		
	Wind	1.2		
Total	**Thermal**	**34,231.1**	**228,406**	**100.0**
	Hydropower	**17,137.1**		
	Geothermal	**114.2**		
	Wind	**1728.7**		

generation [17]. Modern turbines can convert as much as 90.0% of the available energy into electricity whereas the best fossil fuel plants are only about 50.0% efficient [18].

Gross theoretical hydroelectric potential of the world is estimated at 40,150 TWh per annum, where the technically viable hydroelectric potential is estimated at 14,060 TWh per year and the economically viable hydroelectric potential is estimated at 8905 TWh per annum [19]. Approximately 3000 TWh per year of this potential has already been exploited in developed countries [20]. Most of the remaining potential still exists in the developing world especially in Asia, Africa and Latin America as shown in Table 3. Carefully planned hydropower development in these regions could make a vast contribution to improving living stands, because approximately 2 billion people in rural areas of developing countries are still without a reliable electricity supply [21]. Taking as an example, in the BRIC states: Brazil, Russia, India, China hydropower construction in phases served to promote industrialization and economic development [22]. Turkey, which is considered as one of the emerging countries after BRIC, hydropower has been an initiator and promoter of the country's economic development.

Recently, representatives from more than 170 countries have reached a consensus by declaring all hydropower to be renewable and worthy of international endorsement, some of these supporting evidence is summarized below [23,24]

- Hydropower helps the utilisation of other renewable sources,
- Hydropower helps guaranteed energy and price stability,
- Hydropower contributes to fresh water storage,
- Hydropower improves the stability and reliability of electricity grid,
- Hydropower helps fight climate change,
- Hydropower improves air quality,
- Hydropower offers a significant contribution to sustainable development,
- Hydropower offers clean and cheap energy for today and for tomorrow.

Hydropower has unique benefits, rarely found in other energy sources. This can be attributed to the electricity itself, or to side benefits often associated with reservoir development and avoided generation based on fossil fuels [25,26]. The most apparent advantage of hydropower projects in any country where there is sufficiently high hydropower potential exists is associated with the generation of electricity at low costs with fairly small greenhouse gas emissions during operational life time [27]. Furthermore, reservoirs in the hydroelectric power plants allow many other uses besides energy storage such as cost effective development of run of river plants downstream with little environmental impacts and livelihood growth [28].

Despite these benefits hydropower plants can cause the following major environmental problems: loss of agriculturally productive, alluvial bottomland, alteration of ecosystem biogeochemistry, decline in fish species, fluctuations of water levels alter shorelines, cause downstream erosion, and affect water temperature, chemicals, and aquatic communities, sediment build-up limits life effectiveness of the dams to 30 years [29]. In addition, hydroelectric power plants require considerable land for their water storage reservoirs, an average of 750 km^2 of reservoir land area, and 14 trillion l of water are required for the production of 1 TWh per annum [30]. Detailed comparison of the economic, social and environmental advantages and disadvantages of hydropower projects are given in Table 4.

Table 3
Remaining technically and economically feasible hydropower potential in the world [21].

	Technically feasible potential, TWh/year	Economically feasible potential, TWh/year
Africa	1750	1000
Asia	6800	3600
North+Central America	1660	1000
South America	2665	1600

According to the International Energy Agency (IEA) projections, globally hydropower production will grow by an average 2.0% per annum [31]. Over three quarters of the increase is expected in developing or recently developed countries because there are few low cost hydroelectric resources left to exploit in the Organization for Economic Cooperation and Development (OECD) countries [32]. In that context, it is expected that hydropower development would be an extremely important topic in Turkey's Vision 2023 energy agenda. Water is the fundamental source of hydropower, therefore Turkey's water reserves must be analysed prior to focusing on the country's hydroelectric outlook.

3. Water reserves in Turkey

The water reserves of Turkey is explained in the following paragraph based on recent data from the State Hydraulic Works (DSI) [33]: The average annual rainfall in Turkey is 643 $mmkm^{-2}$; this is equivalent to approximately 501 billion m^3 of water per annum. Out of this, 274 billion m^3 is evaporated, 69 billion m^3 supplies the underground water, and the remaining 158 billion m^3 is transferred to seas, lakes and water basins via rivers. In addition, approximately 7 billion m^3 of water is transferred to Turkey via rivers from neighbouring countries and 28 billion m^3 of underground water is transferred to the surfaces via springs and fountains. As a result, it was estimated that Turkey has a gross surface water potential of approximately 190 billion m^3 per annum [33]. Detailed information about average annual rainfall and gross water potential of Turkey's major water basins are reported in Table 5.

Water and its management effects human health, communities' welfare, and ecosystem sustainability [34]. According to a recent report by the United Nations Development Programme (UNDP) Turkey is considered as one of the few “water rich” countries in the Middle East, where scarcity of water resources generally exists [35]. However, this richness is just relative to the countries in the region such as Israel, Jordan, Syria, etc. In reality, Turkey has a water potential per capita of approximately 1600 m^3 [36]. However, a country must have a water potential between 8000 m^3 and 10,000 m^3 per year per capita in order to be considered as water rich [37]. Any country with water supplies between 1000 m^3 and 2000 m^3 per year per capita is considered as water-stressed, and below 1000 m^3 per year per capita as water-scarce [37]. Consequently, Turkey should be considered a water-stressed country with high vulnerability. A recent report by the DSI also pinpoints that Turkey could have water scarcity by 2030 if the reserves are not controlled properly and water is not consumed sustainably [38].

In modern Turkey, water reserves are predominantly controlled by dams. The dams built on the major rivers of Turkey also guarantee the use of the water, when it is necessary, due to considerable variation observed in the runoff in terms of seasons and regions [39]. There are 706 “dam lakes” in Turkey with various sizes. In that context, the surface area of Ataturk Dam is 817 km^2, Keban Dam 675 km^2, Karakaya Dam 268 km^2, Hirfanli Dam 263 km^2, Altinkaya Dam 118 km^2 [33]. The water collected in these dams' is essentially used for three purposes: irrigation,

Table 4
Advantages and disadvantages of hydropower adopted from Refs. [55,56].

Advantages	Disadvantages
Economic aspects	
Provides low operating and maintenance costs	High upfront investment
Provides long life span (50–100 years and more)	Precipitation dependent
Provides reliable service	Requires long-term planning
Includes proven technology	Requires long-term agreements
Instigates and fosters regional development	Requires multidisciplinary involvement
Provides highest energy efficiency rate	Often requires foreign contractors and funding
Creates employment opportunities	In some cases, the storage capacity of reservoirs may decrease due to sedimentation
Saves fossil fuels and helps energy independence by exploiting indigenous resources	–
Optimises power supply of other generating options	–
Social aspects	
Leaves water available for other uses	May involve resettlement
Often provides flood protection	May restrict navigation
May enhance navigation conditions	Local land use patterns will be modified
Often enhances recreational areas	Waterborne disease vectors may need to be checked
Enhances accessibility of the territory and its resources	Requires management of competing water uses
Improves living conditions	Effects of impacted people's livelihoods need to be addressed
Sustains livelihoods (fresh water, food supply)	–
Environmental aspects	
Produces no atmospheric pollutants but only very few greenhouse gas emissions	Inundation of terrestrial habitat
Enhances air quality	Modification of hydrological regimes
Produces no waste	Modification of aquatic habitats
Avoids depleting fossil fuel resources	Water quality needs to be monitored/managed
Often creates new freshwater ecosystems with increased productivity	Temporary introduction of methyl-mercury into the food chain needs to be monitored/managed
Enhances knowledge and improves management of valued species due to study results	Species activities and populations need to be monitored/managed
Helps to slow down climate change	Barriers for fish migration, fish entrainment
Neither consumes nor pollutes the water it uses for electricity generation purposes	Sediment composition and transport may need to be monitored/managed

Table 5
Average annual rainfall and gross water potential of Turkey's major water basins [57].

Name of basin	Rainfall area, km^2	Annual average flow, km^3	Percentage in total, %
Meric-Ergene	14,560	1.3	0.7
Marmara	24,100	8.3	4.5
Susurluk	22,399	5.4	2.9
Northern Aegean	10,003	2.9	1.1
Gediz	18,000	2.0	1.1
Kucuk Menderes	6907	1.2	0.6
Buyuk Menderes	24,976	3.0	1.6
Western Mediterranean	20,953	8.9	4.8
Antalya	19,577	11.1	5.9
Burdur	6374	0.5	0.3
Akarcay	7605	0.5	0.3
Sakarya	58,160	6.4	3.4
Western Black Sea	29,598	9.9	5.3
Yesilirmak	36,114	5.8	3.1
Kizilirmak	78,180	6.5	3.5
Konya (endorheic)	53,850	4.5	2.4
Eastern Mediterranean	22,048	11.1	6.0
Seyhan	20,450	8.0	4.3
Asi	7796	1.2	0.6
Ceyhan	21,982	7.2	3.9
Euphrates-Tigris	184,918	52.9	28.5
Eastern Black Sea	24,077	14.9	8.0
Coruh	19,872	6.3	3.4
Aras	27,548	4.6	2.5
Van lake	19,405	2.4	1.3
Total	**779,452**	**186.9**	**100**

domestic and for electricity generation. The last is the concern of this review.

4. Hydropower in Turkey

Full utilisation of the hydropower potential is at utmost importance according to Turkey's Vision 2023 agenda. Although, Turkey's fresh water reserves have been divided into 25 river basins more than 95.0% of the country's hydropower potential is distributed into 14 river basins. Detailed information about the economically feasible hydroelectric potential of these basins is reported in Table 6. Most of these basins are situated on the mountainous areas of Turkey. Euphrates-Tigris, with its 184,918 km^2 drainage area and elevation range between 500 m and 5000 m, is estimated to uphold 30.0% of the country's hydropower potential [40,41]. Consequently, Turkey has one of the highest hydropower potential in the Middle East. Similarly, the Black Sea region, which has steep and rocky mountains that extend along the coastline, has a considerable hydropower potential. Especially the Eastern Black Sea region is of particular importance, because of its high capacity factor [41].

In Turkey, construction of dams and subsequently hydroelectric power plants started in the second half of the 20th century and augmented thereafter to supply water for irrigation and electricity production. Historically, hydropower is considered as the most important renewable energy source in Turkey. And currently it is the second largest domestic energy source after coal. It was estimated that Turkey has a gross annual hydroelectric potential of 433,000 GWh, which is 14.0% of the total hydropower capacity in Europe and approximately 1.0% of the world [42]. Almost half of this gross potential is technically exploitable, 216,000 GWh, and 28.0% or 127,381 GWh is economically exploitable [43].

At the end of 2011, there were more than 275 hydropower plants in operation in Turkey with a combined installed capacity of approximately 16,600 MW and an annual average generation of nearly 58,250 GWh [44]. As a result, only 27.0% of the technical

Table 6
Economically feasible hydroelectric potential of Turkey's basins [40].

Name of basin	Economic potential, GWh/year
Euphrates	37,961
Tigris	16,751
Eastern Black Sea	11,062
Coruh	10,540
Seyhan	7571
Kizilirmak	6320
Yesilirmak	5297
Eastern Mediterranean	5029
Antalya	5163
Ceyhan	4652
Western Mediterranean	2534
Sakarya	2373
Aras	2287
Western Black Sea	2176
Susurluk	1602
Others	1722
Total	**123,040**

Table 7
Hydropower plants in Turkey at the end of 2011 [44].

Producer	Installed capacity, MW	Projected production capacity, GWh	Estimated safe production capacity in 2012, GWh
Electricity Generation Company (EUAS)	11,589.6	40,264.4	40,648.2
Operating Rights Transferred Producers	127.9	182.6	137.9
Independent Power Producers	3923.7	14,470.0	8004.0
Build-Operate-Transfer Producers	952.8	3350.0	3350.0
TOTAL	**16,594.0**	**58,267.0**	**52,140.1**

and 46.0% of economically feasible hydroelectric potential of Turkey is utilised for electricity generation. As a result, there is still considerable untapped hydroelectric potential for further growth. It is estimated that approximately 60,000 GWh of hydroelectric potential could be added to the grid.

The hydropower market or in general Turkey's electricity sector is still predominantly controlled by public companies and the country's deep rooted statist tradition is likely to be the main problem in front of market privatization [45]. At the end of 2011, the public sector controlled approximately 70.0% of the hydroelectricity market under the umbrella of the Electricity Generation Company (EUAS). Only the remaining 30.0% is in the hands of Operating Rights Transferred Producers (ORTPs), Independent Power Producers (IPPs), and Build-Operate-Transfer Producers (BOTPs) private sector companies. In the same year, EUAS had an installed hydroelectric capacity of nearly 11,590 MW with net generation of 40,648 GWh [44]. Whereas ORTPs had 128 MWh installed capacity with net generation 138 GWh, IPPs had 3924 MW installed capacity with 8004 GWh net generation and BOTPs had 953 MW installed capacity with 3350 GWh net generation [44]. Totalling up to 16,600 MW of installed hydroelectric capacity and 52,140 GWh net electricity generation at the end of 2011. Detailed information about installed, projected and safe production capacities of Turkey's hydropower plants are given in Table 7.

Turkey's hydroelectric capacity is really impressive and the idea of further growth in the market seems to be really promising. However, by looking at the bigger picture it is clearly seen that Turkey's electricity market is dominated by imported fossil fuels. And share of hydropower in the country's total annual electricity generation has been constantly decreasing since 1990 as shown in Fig. 1. For decades, the target of Turkish energy policy is to supply cheap electricity in sufficient amount and on time under qualified, reliable and competitive conditions of the energy market [46]. However, due to problems in short and long term energy policy planning and Turkey's unexpected economic growth there has been a misbalance with the actual electricity consumption and installed capacity. In 1990s due to the country's sudden economic growth both the public and private sector shifted to natural gas fired power plants as the primary source for electricity generation. This was due shorter construction and commissioning period and lower initial capital investment required. Consequently, the share of hydropower in Turkey's total electricity generation sharply decreased to 25.0% in 2011.

Today, Turkey once again plans to increase the share of renewable energy sources in the country's electricity generation. To be specific, 30.0% share by 2023. However, it is quite shocking to see more than 42.0% of Turkey's electricity generation was supplied from hydropower or simply from renewable energy between 1990 and 1995. Thus today's Turkey is just struggling to reach those renewable energy levels once the country had. This clearly shows the importance of medium and long term energy strategies and development plans. Consequently, feasibility of Turkish government's ambitious goal to fully utilize the country's technical hydroelectric potential must be analysed in detail to prevent such a blunder again.

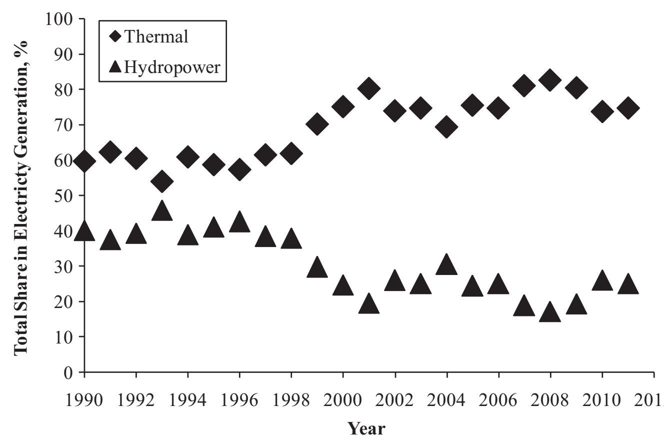


Fig. 1. Share of thermal and hydropower in Turkey's total electricity generation between 1990 and 2011 [53].

5. Future of hydropower in Turkey: projections between 2012 and 2023

The future of hydropower sector in Turkey depends on the size and commissioning periods of the HEPPs that are still under construction. Turkish Electricity Transmission Company's (TEIAS) envisaged that all the hydroelectric power plants under construction would be operational until 2016 [44]. Meanwhile, the Energy Market Regulatory Authority (EMRA) generated two scenarios based on installed capacity and progress rate, %, data about the commissioning years of these hydropower plants as shown in Table 8. Using these EMRA scenarios TEIAS forecasted the installed hydropower capacity and hydroelectricity generation projections between 2011 and 2021, which is shown in Table 9.

Table 8
Parameters for hydropower scenarios [44].

Scenarios	Progress rate	Installed capacity	Date of commissioning
Scenario 1	≤10%	All	Unclear
	Between 10%–35%	≤100 MW	2014
	Between 10%–35%	Between 100 MW and 1000 MW	2015
	Between 10%–35%	≥1000 MW	2016
	Between 35%–70%	≤100 MW	2013
	Between 35%–70%	Between 100 MW and 1000 MW	2014
	Between 35%–70%	≥1000 MW	2015
	≥70%	All	2012
Scenario 2	≤10%	All	Unclear
	Between 15%–40%	≤100 MW	2014
	Between 15%–40%	Between 100 MW and 1000 MW	2015
	Between 15%–40%	≥1000 MW	2016
	Between 40%–80%	≤100 MW	2013
	Between 40%–80%	Between 100 MW and 1000 MW	2014
	Between 40%–80%	≥1000 MW	2015
	≥80%	All	2012

Table 9
Turkey's installed hydropower capacity and hydroelectricity generation projections based on two scenarios, between 2012 and 2023 [44].

Year	Scenario 1		Scenario 2	
	Installed capacity, MW	Electricity generation, GWh	Installed capacity, MW	Electricity generation, GWh
2012	20,470	65,463	19,667	64,158
2013	21,461	72,934	20,893	70,698
2014	24,291	79,651	23,085	76,555
2015	28,003	90,522	25,883	84,380
2016	31,606	104,443	29,143	96,511
2017	33,394	112,708	31,706	106,626
2018	33,815	115,779	33,815	113,652
2019	33,815	116,558	33,815	116,558
2020	33,815	116,558	33,815	116,558
2021	33,815	116,558	33,815	116,558
2022	33,815	116,558	33,815	116,558
2023	33,815	116,558	33,815	116,558

Table 10
Turkey's electricity demand forecast, between 2012 and 2023.

Year	Electricity demand, TWh	
	TEIAS forecast[a] [44]	Author's previous forecast [13]
2012	318.5	228.7
2013	329.1	246.9
2014	343.3	266.5
2015	375.6	287.7
2016	407.1	310.6
2017	417.3	335.3
2018	421.3	361.9
2019	426.0	390.7
2020	434.7	421.8
2021	443.1	455.3
2022	N/A	491.5
2023	N/A	530.6

[a] Based on Scenario 1 (maximum values from two scenarios).

Table 11
Hydropower's supply rate of Turkey's total annual electricity demand, between 2012 and 2023.

Year	% of the Total annual electricity demand			
	Scenario 1		Scenario 2	
	Calculated based on TEIAS projection [44]	Current study	Calculated based on TEIAS projection [44]	Current study
2012	20.6	28.6	20.3	28.1
2013	22.2	29.5	21.8	28.6
2014	23.2	29.9	22.7	28.7
2015	24.1	31.5	23.4	29.3
2016	25.7	33.6	25.0	31.1
2017	27.0	33.6	26.7	31.8
2018	27.5	32.0	27.6	31.4
2019	27.4	29.8	27.6	29.8
2020	26.8	27.6	27.0	27.6
2021	26.3	25.6	26.5	25.6
2022	N/A	23.7	N/A	23.7
2023	N/A	22.0	N/A	22.0

TEIAS estimated that Turkey's electricity demand would reach to either 467.3 TWh or 424.8 TWh in 2021 based on high and low demand forecasts [44]. However, even the high energy demand forecast is much lower than the predictions reported in the literature. Hamzacebi estimated that Turkey's energy demand in 2020 would reach to 499.6 TWh [47]. Similarly, Ozturk and co-workers estimated that the demand would increase to approximately 500.0 TWh [48], and Unler as 555.7 TWh [49] in 2020. The official projections are only higher than the forecasts published by Tunc and co-workers as approximately 320.0 TWh in 2020 [50]. Finally, in a recent study by the author of this paper, Turkey's electricity demand in 2023 was estimated at 530.0 TWh [13]. In order to make a sound judgement the electricity demand forecast previously generated by the author was used for comparison with the average TEIAS forecasts as shown in Table 10.

It has been reported that the official forecasts for energy demand in Turkey generally predicted much higher values than the consumption actually occurred [51]. There may be several reasons of these official projection failures and others conducted research to identify and analyze the causes of failures in energy forecasting studies [52]. In 2011, nearly 57.5 TWh of electricity was generated from hydropower supplying more than 25.0% of Turkey's electricity demand. However according to official projections at the same year hydropower should supply 19.6% of Turkey's electricity demand. This 6% difference between the actual generation and the official projections is simply due to the overestimation of the country's electricity demand at the same year. As can be seen from Table 10, the official forecast for electricity demand till 2019 is higher than the predictions generated in this study. More importantly and interestingly, after 2020 the official projections are lower than the forecasts of the author and other results published in the literature. From academic and industrial perspective that was definitely worth investigating. Accordingly, using the scenarios and projections for hydroelectric capacity and generation given in Table 9, and the forecasts in Table 10 hydropower's supply rate of Turkey's total annual electricity demand between 2012 and 2023 was calculated and reported in Table 11.

Both the official and current forecast suggested that hydropower's supply rate in Turkey's electricity demand will increase until 2019 and then start to decrease. The assessment based on the official projections showed that the supply rate would increase up to 27.5% in 2018 and decrease to 26.3% in 2021. Consequently, the official and current assessment seems to be coherent with the Vision 2023 goals. The remaining approximately 4.0% gap from the official forecast could be supplied from wind, solar and geothermal

power plants making a total of 30.0% renewable energy based electricity supply in 2023.

As a key discussion point, if the official projections are overestimating the country's electricity demand than there would be a serious demand gap and this must be analysed in detail. To be specific, the forecast generated in this study clearly shows that more than 31.5% of the country's electricity demand could be uniquely supplied from hydropower by 2017 if the HEPPs would become operational in 2016 based on the scenarios and projections given in Tables 8 and 9. Consequently, reaching the Vision 2023 renewable energy goal six years earlier. However, after surpassing this threshold the hydropower's supply rate would drastically decrease to 22.0% in 2023. Therefore, 8.0% or approximately 45.0 TWh demand gap should be provided to reach the Vision 2023 renewable energy goal. As a result, the country's wind, solar and geothermal based capacity should provide the remaining 4.0% or 22.5 TWh of electricity.

6. Conclusion

This study clearly showed the utmost importance of accuracy in energy demand projections and hydropower's unique position in Turkey's electricity market. Currently, hydropower is the primary renewable energy source in Turkey, supplying nearly 25.0% of the country's electricity demand. Both the official TEIAS and the forecast generated in this study showed that between 22.0% and 27.0% of Turkey's electricity demand at the year 2023 should be supplied from hydropower. This is equal to approximately 116.0 TWh of electricity. Considering the total wind and geothermal generation in 2011 at approximately 7.0 TWh, hydropower would definitely facilitate the growth of other renewable energy sectors to close the demand gap in the Vision 2023 renewable energy goals. As a result, between 22.5 TWh and 45.0 TWh of electricity should be generated from renewable energy sources other than hydropower in the next decade. If the investments will be carried out as planned and the goals in Vision 2023 agenda can be achieved, see Table 2, this demand gap can be easily fulfilled by wind and solar energy. Conclusively, this study can be further used as a foundation for the analysis of hydropower systems in Turkey by the academic community and the private sector.

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